A Utilization Perspective on Current and Emerging Biofuels

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Research Supported by
US DOE Office of Vehicle Technologies
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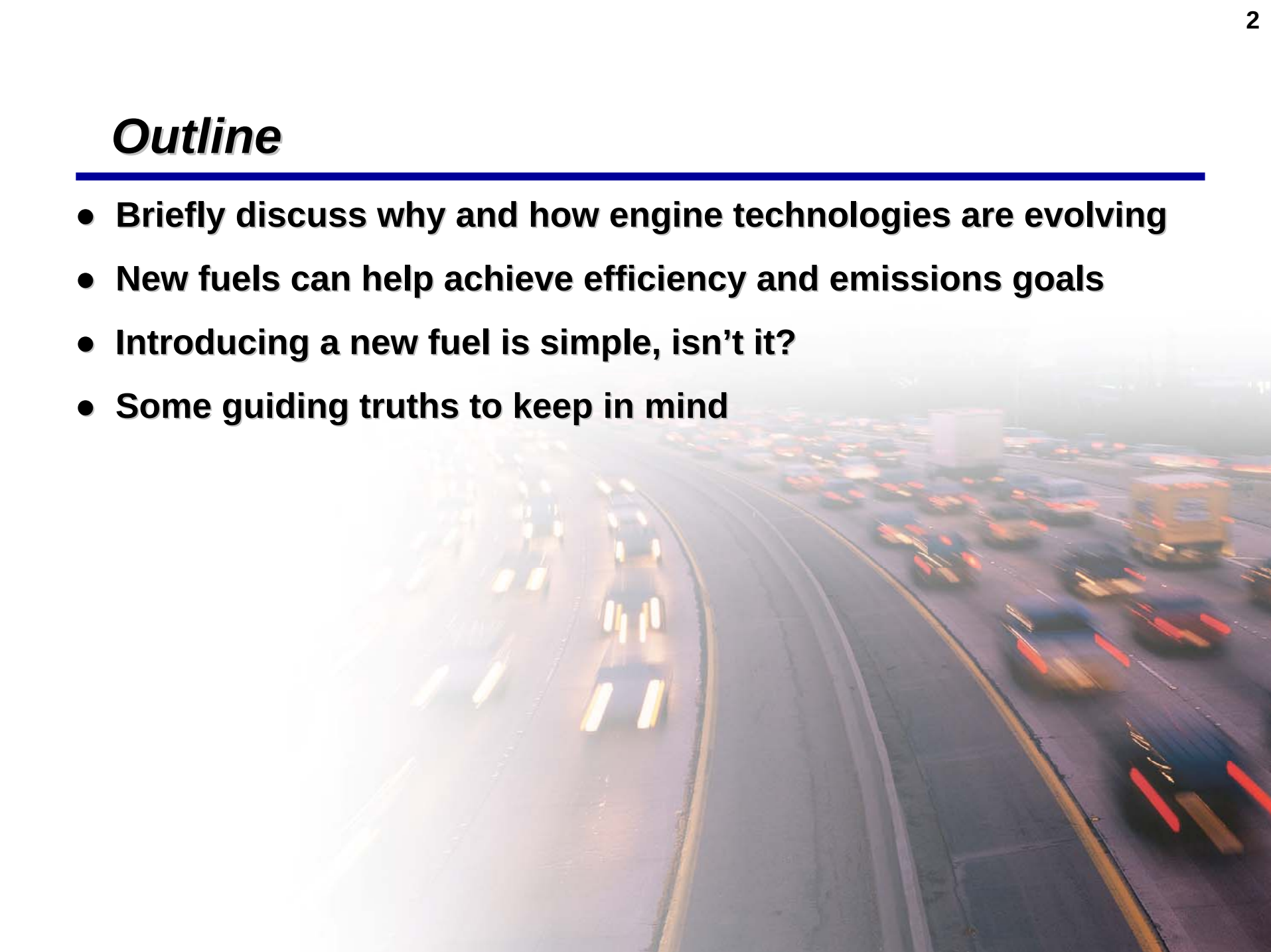
Biomass 2009: Fueling Our Future
Gaylord National Hotel, National Harbor, Maryland
March 18, 2009

Outline

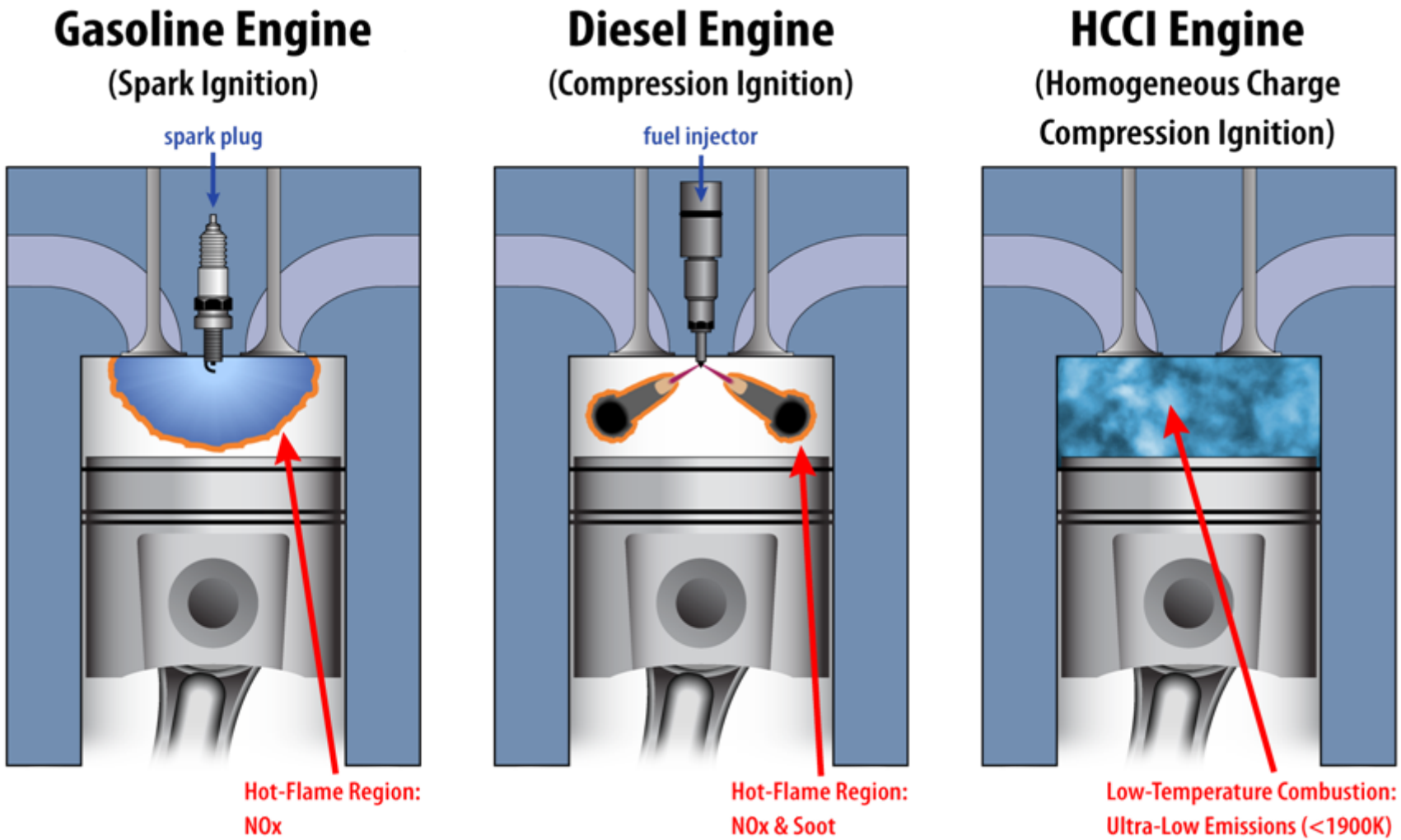
- **Briefly discuss why and how engine technologies are evolving**
- **New fuels can help achieve efficiency and emissions goals**
- **Introducing a new fuel is simple, isn't it?**
- **Some guiding truths to keep in mind**



Factors Driving the Evolution of Transportation Engines and Fuels

- **Energy security**
- **Environmental consequences**

Reciprocating Engines Are Evolving

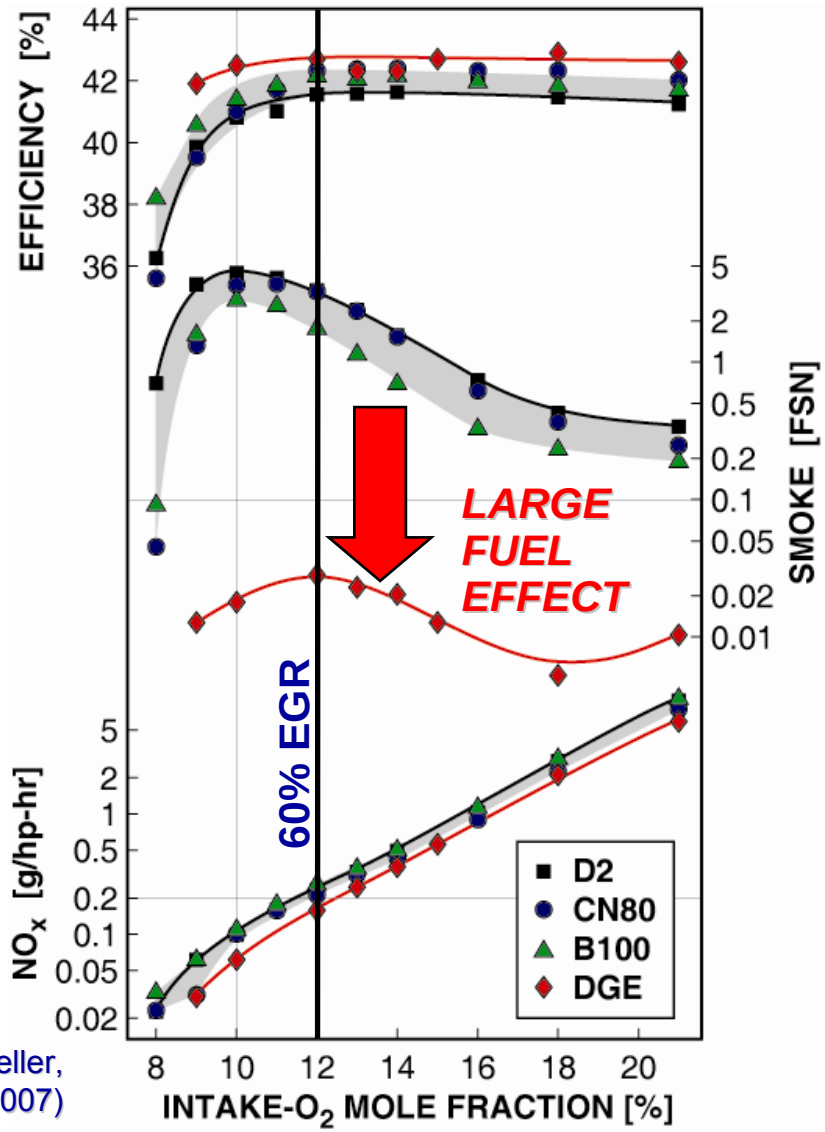


Reciprocating Engines Are Evolving (cont'd)

- **Desire for increased efficiency is driving today's diesel and gasoline engines toward a common configuration:**
  - **Unthrottled**
  - **Compression ratio higher than today's spark-ignition**
  - **Compression ignition (perhaps with ignition assist)**
  - **Turbocharged**
  - **"Partially premixed" charge**
- **HCCI isn't the only promising advanced-combustion strategy**
  - **Mixing-controlled, high-efficiency, clean combustion (HECC)**
- **The optimal combustion strategy has yet to emerge**
- **Optimal fuel characteristics may be significantly different for different combustion strategies**
  - **Highly premixed (HCCI): difficult to autoignite, higher volatility**
  - **Mixing-contr. HECC: easy to autoignite, lower volatility, oxygenated**

New Fuels Can Help – But They May Cause New Problems, Too

- **Highly oxygenated fuel can help break long-standing trade-offs**
  - **Mixing-controlled HECC**
  - **Cooled EGR and/or NO_x aftertreatment required (low S, P content of fuel enables use of more-active catalysts)**
  - **3 Mbpd of DGE not available!**
- **Fuel changes can lead to higher emissions (*e.g.*, biodiesel NO_x ↑)**
  - **Need to understand fuel effects on combustion**
  - **Fuel molecular structure matters: Ethers are better than esters for smoke reduction due to prompt CO_2 production from esters**



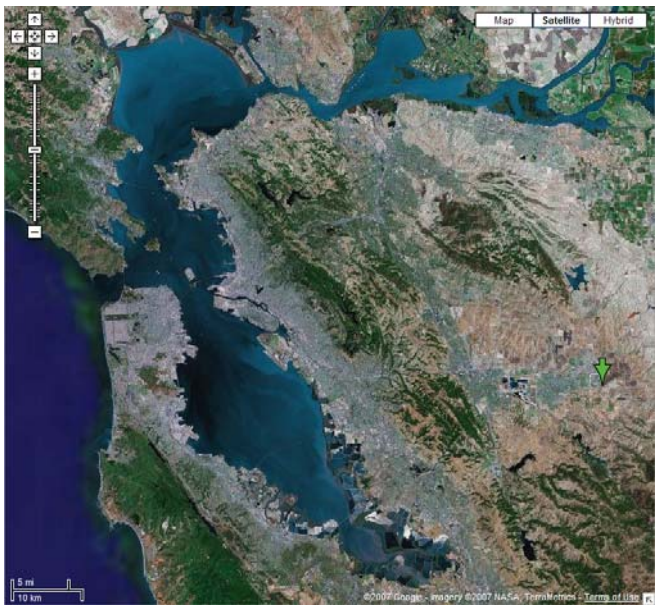
Source: Cheng, Upatnieks, and Mueller, *Energy and Fuels* **21**:1989-2002 (2007)

Introducing a New Fuel Is Simple… NOT!

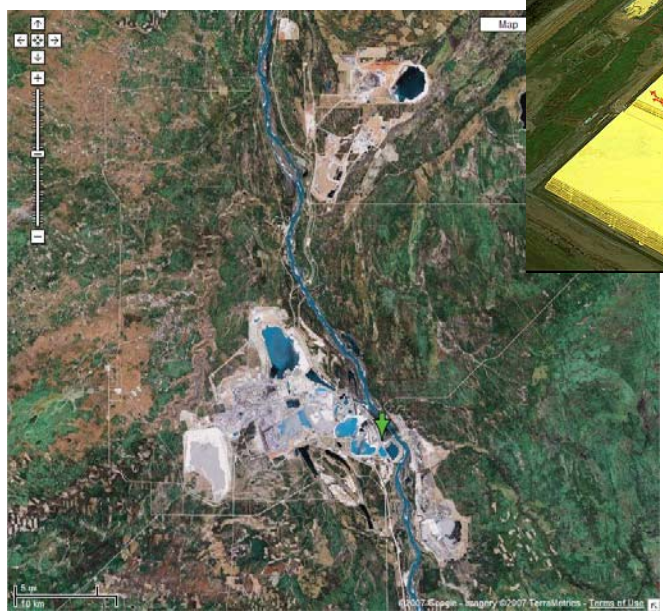
- **"Fit for purpose" ≡ fuel meets all customer requirements**
  - **Customers include**
    - Vehicle operators, engine manufacturers, and fuel distributors
    - Also investors, environmentalists, politicians, …*everyone!*
- **Customer requirements**
  - **Cost ($/J), ignition quality, distillation curve, availability, variability, energy density, oxidative and biological stability, lubricity, cold-weather performance, elastomer compatibility, corrosivity, efficiency, emissions (regulated and unregulated), viscosity, flash point, low-temperature heat release, metal content, odor/taste thresholds, solubility in base fuel, water tolerance, specific heat, latent heat, toxicity (acute, chronic, reproductive), environmental fate, sulfur/ phosphorus content, GHG reduction, …**
  - **What you don't know about fuel properties can hurt you**
    - Ethanol elastomer incompatibilities (late 1970s), MTBE odor and taste thresholds (late 1990s), biodiesel cold-flow performance and NO_x emissions (early 2000s to today)

The Scale of the Problem Is Important

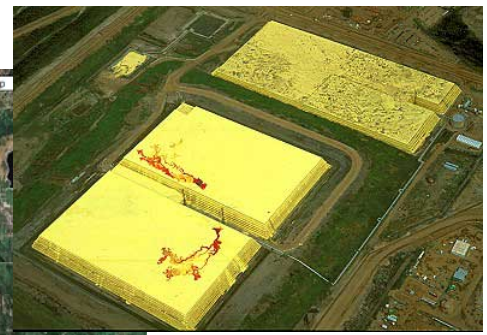
- **US consumes ~20 Mbpd of petroleum**
  - **Would fill a container 100 yd x 53.3 yd x ~1/2 mile deep *every day***
- **Refinery operation = conservation of mass on a grand scale**
  - **Everything that goes in must come out as marketable products**
  - **A "minor" detail may have major consequences**



San Francisco Bay Area



Fort Mackay, Alberta, Canada



Canadian sulfur "pyramids"

Source: Google Maps (http://maps.google.com)

Systems Analysis Is an Important Tool – But It Can Only Take Us So Far

- **Feedstock, conversion technique, and final fuel specifications must be considered together for true process optimization**
- **Systems analysis can assist in avoiding known pitfalls and providing initial "best guess" configuration, but…**
- **With any new endeavor, there are**
  - **Knowns**
  - **Known unknowns**
  - **And *unknown unknowns***

These must be learned the hard way

- **There will be an Edisonian component to the introduction of any new fuel, and we must be prepared to "fail our way forward"**

Some Guiding Truths to Keep in Mind

- **Increased efficiency is key goal of new engine technologies; compliant emissions enable market penetration**
  - **Engines are evolving to a common hardware configuration**
  - **Best combustion strategy unclear → fuel requirements may diverge**
- **New fuels can provide high efficiency and compliant emissions with less aftertreatment required**
  - **Biofuels will be blended with petroleum fuels and expected to meet existing specs**
  - **Some molecules are better than others, need fundamental understanding of fuel effects for guidance**
- **Thinking of introducing a new fuel?**
  - **The devil is in the details of "fit for purpose"**
- **Scale of the fuel-supply problem must not be underestimated**
  - **What happens to any biomass that isn't converted into fuel?**

Some Guiding Truths to Keep in Mind

- **Analysis should be used to avoid known pitfalls, but it alone cannot identify an optimal system**
  - **Unknown unknowns cannot be anticipated**
  - **We must be prepared to fail our way forward**

Thank you for your attention!